



HOW FIRE IS IMPACTING THE INDIGENOUS LANDS OF THE BRAZILIAN CERRADO: THE CASE OF SÃO MARCOS AND MERURE INDIGENOUS LANDS IN MATO GROSSO, BRAZIL

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Abstract: This study investigates the impact of wildfires on Indigenous Lands in the Brazilian Cerrado, focusing on the São Marcos and Merure territories of the Xavante and Bororo people from 1985 to 2023. Despite representing less than 2% of the Brazilian Cerrado, indigenous lands are crucial for the conservation of cultural heritage and biodiversity. Utilizing data from the Brazilian Biomes Mapping Project (MAPBIOMAS), this research highlights how changes in land cover and use, combined with climate change and significant wildfire events, are exacerbating challenges in São Marcos and Merure indigenous lands in the Mato Grosso, threatening to ecosystems and traditional ways of life. The results show that show an intensification of fire activity in the Merure and São Marcos Indigenous Lands from 1985 to 2023, with a marked increase in burned area starting in 2000.

Keywords: Indigenous People, Indigenous Lands, Brazilian Cerrado, Fire.



1. Introduction

The Brazilian Cerrado is the second largest biogeographic system in Brazil and South America, encompassing the most biodiverse savanna in the world (STRASSBURG, 2017). One of its main characteristics is the high degree of endemism among its fauna and flora (RATTER et al., 1997). The Brazilian Cerrado is notable for its remarkable diversity of phytophysognomies and a complex mosaic of different landscapes, ranging from those associated with grasslands to those linked to forest environments (RIBEIRO and WALTER, 2008). In addition to its natural wealth, the Cerrado Domains is a culturally dynamic and vibrant territory, inhabited by various ethnic groups and traditional communities that preserve ancestral practices and knowledge (ALMEIDA, 2005). These practices reflect a deep connection to the land, further enriching this significant natural domain of Brazil (BARBOSA, 2011).

Indigenous Lands account less than 2% of the total area of the Cerrado domains in Brazil, despite this; they play a crucial role in conserving the few remaining continuous landscapes associated with its natural vegetation cover (MOTA JUNIOR, SILVA e SILVA, 2021). Overall, the Indigenous Lands of the Cerrado consist of small, isolated fragments surrounded by land uses primarily related to agriculture and even mining (ARAÚJO et al., 2006). The fragmentation and degradation caused by these activities not only compromise the ecological integrity of Indigenous territories but also profoundly impact local biodiversity and the sustainability of the ecosystem services these areas provide (WELCH, et al., 2013). Furthermore, this pressure on Indigenous lands has intensified territorial conflicts and challenges related to the preservation of cultural heritage and the traditional way of life of the communities (ALMEIDA, 2022).

Given this situation, an scenario of pressure, Porto Gonçalves (2016) and CIMI (2019) emphasize that the gradual increase in conflicts and socio-environmental impacts associated with Indigenous people and their territories is primarily explained by the progressive expansion of agricultural and mining activities. Due to the direct and indirect influences exerted on their territories, indigenous people face daily challenges related to their social reproduction in accordance with their customs and traditions (SILVA, 2016; SILVA, SILVA and SOUZA, 2022).

In recent decades, and more intensely in recent years, the devastation and degradation of Indigenous lands caused by wildfires have become a serious issue (ROCHA and NASCIMENTO, 2022). Although in many Brazilian Indigenous cultures, such as that of the Xavante, the use of fire for clearing fields and group hunting is a traditionally established practice and a right guaranteed by the 1988 Brazilian Constitution (BRASIL, 2016), there is still limited understanding of whether the fires spreading across Indigenous territories are due to natural factors or human activities.

Considering the historically observed fire patterns, it is understood that the devastation of Indigenous lands by fire is associated with a broader and more complex process occurring throughout the Brazilian Cerrado, as evidenced by the significant increase in the number of heat hotspots related to fires (WELCH et al., 2013; ROCHA and NASCIMENTO, 2022). According to data from the Brazilian Biomes Mapping Project (MAPBIOMAS, 2023), between 1985 and 2020, among the ecosystems that make up Brazil's environmental matrix, the Cerrado had the highest proportion of burned area, with approximately 733,851 km² burned, an amount significantly greater than that recorded in the Brazilian Amazon. This highlights not only the



concerning case of vulnerability of the human-environment system (traditional communities and biodiversity) in the Brazilian Cerrado, but also the need for public policies as essential tools to reduce the impacts on the territories.

In the course of the period of the year 1985 to 2023, the data indicate that fire impacted 40% (792,204 km²) of the Brazilian Cerrado, with 63% burning more than once, where revealed human-induced changes in the fire regime, originally shifting from July to September to a new fire season from August to October (ARRUDA et al., 2024). The data also reveal that the most part of the areas affected by these fires are associated with natural vegetation cover, predominantly areas mapped as Savanna Formations and Grassland Formations, respectively.

Throughout the evolutionary process of Brazil's environmental matrices, from the Quaternary to the present, fire has emerged as one of the main regulatory agents, i.e., balancing forces, of the ecosystems within the Cerrado Biogeographical System, especially its open spaces (COLE, 1984, 1960; BARBOSA, 2002, 2011). Recent studies have demonstrated that, in the context of global climate change (IPCC, 2022), the Brazilian Cerrado is becoming hotter and drier (HOFMANN et al., 2021; HOFMANN et al., 2023), conditions that may significantly increase the susceptibility to wildfires (SETZER, SISMANOGLU AND SANTOS, 2019).

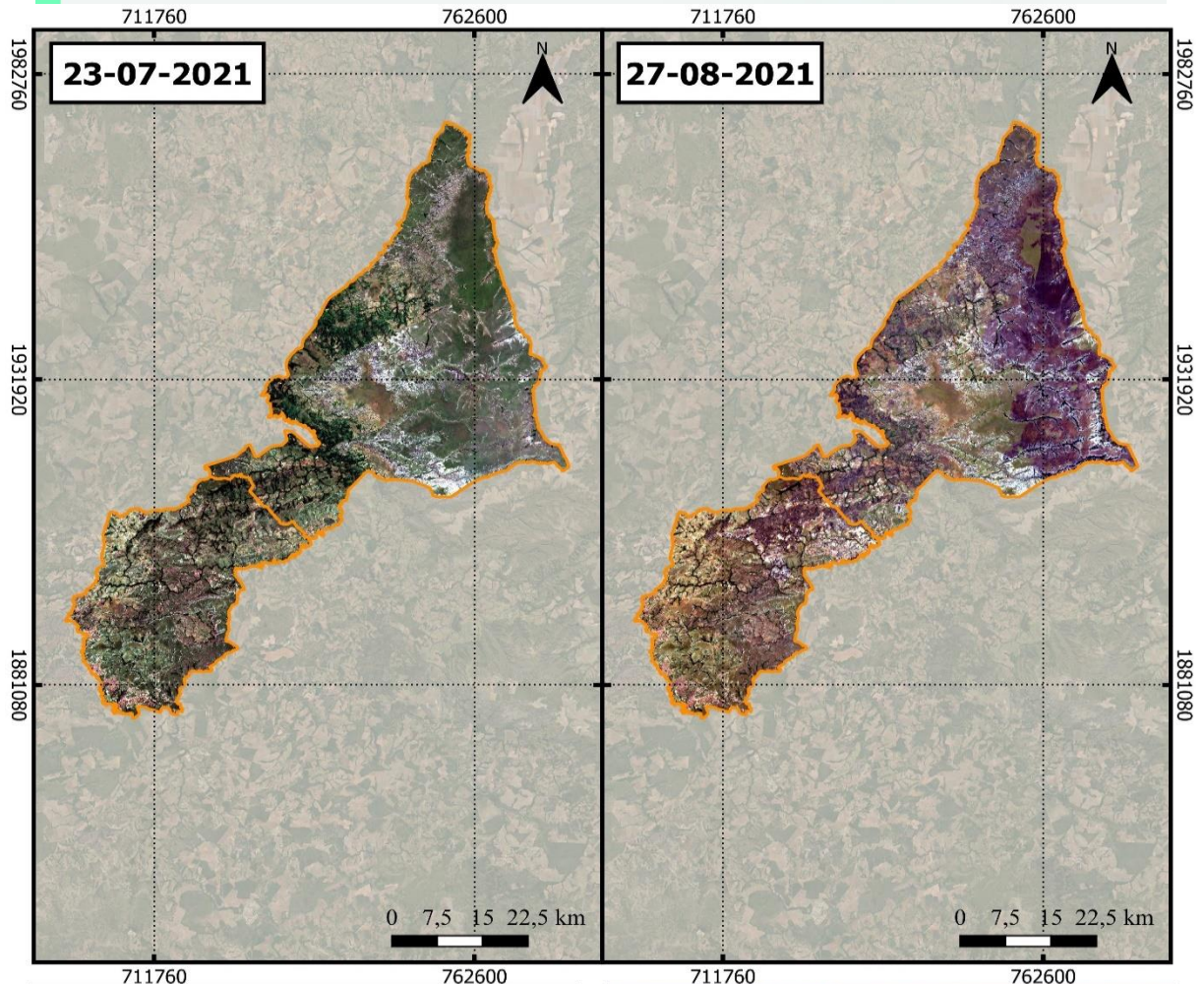
In this context, this study aims to analyse the burned area in the São Marcos and Merure Indigenous Territories, belonging to the Xavante and Bororo people, respectively, in the state of Mato Grosso (1985-2023). The study is based on one of the products (annual burned area) available through the Brazilian Biomes Mapping Project, obtained from Digital Image Processing (DIP) of medium spatial resolution (30 m) satellite imagery, using analysis-ready multispectral data from Landsat (5, 7, 8) sensor systems. The use of remote sensing data has proven essential for the detection, mapping, and monitoring of ecosystems affected by fire owing to its capability for constant observation of large areas (SCHMIDT and ELOY, 2020).

The recurrence of large fire events (wildfires and forest fires) is yet another threat to indigenous people. Pressures such as agricultural expansion, deforestation, mining, and illegal burning compromise both natural resources and the culture and livelihoods of indigenous communities (MOTA JUNIOR, TRENTIN and SILVA, 2023). In this context, the study is justified by the need to understand how these fire-related events are affecting the indigenous lands and amplifying their vulnerabilities. Understanding these processes is crucial to support the development of effective public policies that protect the territories and ensure traditional ways of life, as well as the preservation of biodiversity. Considering a scenario of climate change and an increasingly hot and dry Cerrado (IPCC, 2023; HOFMANN et al., 2021), which intensifies the frequency and severity of wildfires, further exacerbates this situation, creating a cycle of environmental degradation that threatens the survival of local communities.

2. Methodology

2.1 The study area

The study area includes the São Marcos and Merure indigenous lands, situated in the mato-grossense Cerrado, which are inhabited by the Xavante and Bororo indigenous people. This is a region characterized by rich biodiversity, situated in an ecotone between the Cerrado and the Amazon Rainforest, and has been intensely affected by changes in land cover, especially with the advancement of agricultural frontiers (MOTA JUNIOR, TRENTIN and SILVA, 2023).



Legend:

-  São Marcos Indigenous Land (Xavante People)
-  Merure Indigenous Land (Bororo People)
-  Indigenous Lands of the Brazilian Cerrado
-  Federal Units of Brazil

Projection: UTM (Universal Transverse of Mercator)
 Zone: 22 South Hemisphere
 Datum: SIRGAS 2000
 Data Source: ESA, 2023; IBGE, 2023; MMA, 2023.
 Date of Preparation: 25-08-2024
 Org.: The authors.



Figure 1. Situational map of the study area, Mato Grosso, Brazil, highlighting a wildfire event in mid-August 2021. Org.: The authors.



2.2 Data source and properties

The theoretical-methodological approach of the present study consisted of (1) a literature review on the topic and, as previously mentioned, (2) an analysis of data provided by the project MapBiomias (ALENCAR et al. 2022), derived from the digital processing of orbital remote sensing data. Specifically, the first stage, namely the literature review stage, involved the research, selection, reading, and summarization of scientific articles published in national and international journals, as well as chapters from books and entire books. The second stage, in turn, involved the research, acquisition, organization, processing, and analysis of data related to the annual burned area, considering the temporal range from 1985 to 2022.

In the context of research and acquisition of geospatial data, it is noteworthy that the procedural routine occurred as follows: (2.1) acquisition of the geospatial data (shapefile) pertaining to the boundaries of Indigenous Lands from the database of the National Foundation for Indigenous People – FUNAI. Next, (2.2) acquisition of the geospatial data (raster) related to the burned area from 1985 to 2023 from the MapBiomias database, considering data from collection 3.0. Finally, (2.3) acquisition of the total burned area in tabular format, which was organized in a DataFrame format and subsequently analyzed using Microsoft Excel resources for the creation of charts. Using the geospatial data (raster) related to the burned area from 1985 to 2023, a fire frequency map was created out.

2.3 Data processing

To detect years with anomalous values in relation to the annual burned area time series (1985-2023), we applied equations 1, 2, and 3 to the dataset, respectively.

(1):

$$\mu = \frac{1}{(n)} \sum_{i=1}^n xi$$

μ = represents the average burned area over the years (1985-2022).

n = corresponds to the total number of observations for the burned area data ($n = 38$).

xi = is the burned area (hectares) for the respective year.

(2)

$$\sigma = \sqrt{\frac{1}{(n)} \sum_{i=1}^n (xi - \mu)^2}$$

σ = Standard deviation of the burned areas (1985-2023).

Equation 3 was applied to highlight years deemed "Anomalous," based on the annual burned area.



(3)

$$xi > \mu + 2\sigma \text{ or } xi < \mu - 2\sigma$$

In order to identify the areas most affected by wildfires over nearly five decades (1985-2023), and to provide accurate information for environmental and resource management in the context of the Merure and São Marcos Indigenous Lands, we applied equations 4 to create a wildfire recurrence map.

(4)

$$R(i, j) = \sum_{i=1}^{N=48} P(i, j, n)$$

$R(i, j)$ = represents the pixel value at the position (i, j) of the wildfire recurrence map.

P = represents the pixel value at the position (i, j) of the binary map corresponding to the year n . In the binary maps, the values of (i, j) is 1 when there is a record of burning in the year n ; and 0 for when there is no record of burning in the year n .

3. Results and discussions

In Figure 2, we present the time series (1985-2023) of the area affected by fire (in hectares and %) in the São Marcos and Merure Indigenous Lands. The red bars highlight years in which the values of the area affected by fire are considered anomalous in the time series analyzed. The graphs show an intensification of fire activity in the Merure and São Marcos Indigenous Lands from 1985 to 2023, with a marked increase in burned area starting in 2000. Major fire events within these territories are highlighted by peaks in years such as 2010 and 2017, underscoring the vulnerability of these lands and its populations. These events not only result in significant losses of biodiversity, but also affect the availability of resources, jeopardizing the livelihoods of local communities and exacerbating the socio-economic challenges.

The data indicate that the Merure Indigenous Land has experienced significant fire impacts over the past decades. In 2001, the burned area totaled 27,771.82 hectares, representing 11% of the territory. By 2014, the impact was even more pronounced, with 47,901.12 hectares burned, accounting for 19% of the total area. The temporal analysis reveals that, although some years show a relatively low percentage of the affected territory, there is a discernible trend of increasing areas impacted by fire. The significant increase in the burned area in the years 2014, 2016, 2018, and 2020, where 47,901.12 hectares (19%), 41,344.82 hectares (16%), 35,465.46 hectares (14%), and 41,606.24 hectares (16%) were recorded, respectively, underscores the impact of fire in these territories.

In the São Marcos TI, data indicate that the impacts of fire have been even more pronounced when compared to the Merure TI. In 2010, approximately 113,104.3 hectares of the TI were affected by fire, corresponding to 44% of the territory. In 2019, the impact was even greater, marking one of the most critical years, with 124,639.2 hectares burned, representing 49% of the total area. These data indicate an intense pressure on native Cerrado vegetation and reflect the vulnerability of the São Marcos TI (Xavante people) to fire events caused by factors that are as yet little known.

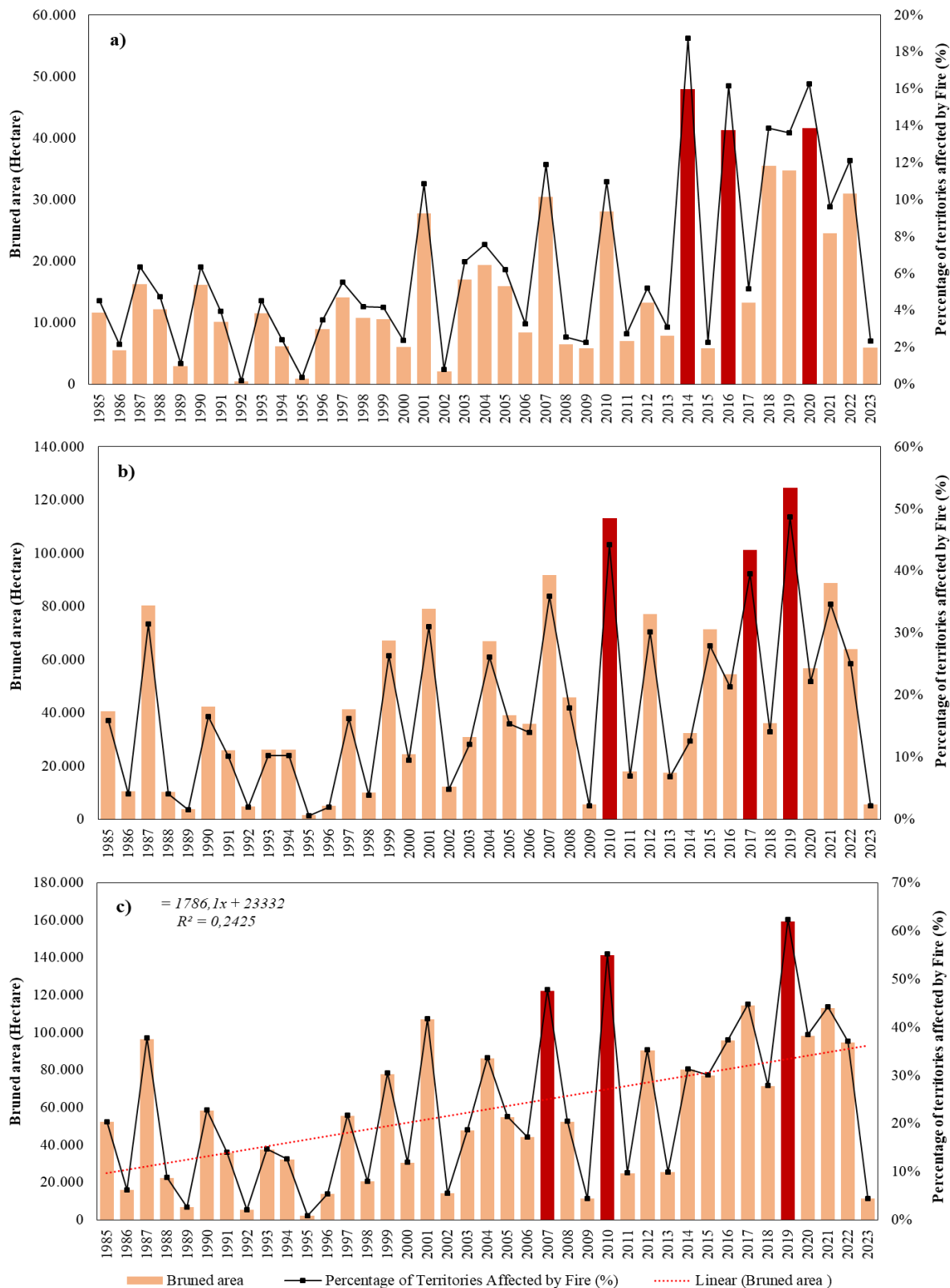


Figure 2. Annual burned area in Merure (a) and São Marcos (b), and both TI (c), between 1985 and 2023. Org.: The authors.



Although also affected by fire, the Merure Indigenous Territory (TI) exhibited smaller burned areas compared to the São Marcos TI. This difference suggests that the fire dynamics between the two lands may be influenced by differences in land use practices, variations in vegetation aspects, as well as in management practices. In this regard, the comparative analysis of fire data highlights the need for adaptive and integrated interventions that consider the particularities of each territory, aiming not only for the protection of affected areas but also for the promotion of sustainable practices that reduce the incidence of wildfires, in accordance with the habits and cultural customs of their peoples. In this context, aiming to directly contribute to decision-making, we present the map of Burn Recurrence Index in TIs over the last 39 years, as presented in Figure 3. This data allows for visualization of the areas of TIs where there has historically been a higher frequency of fire.

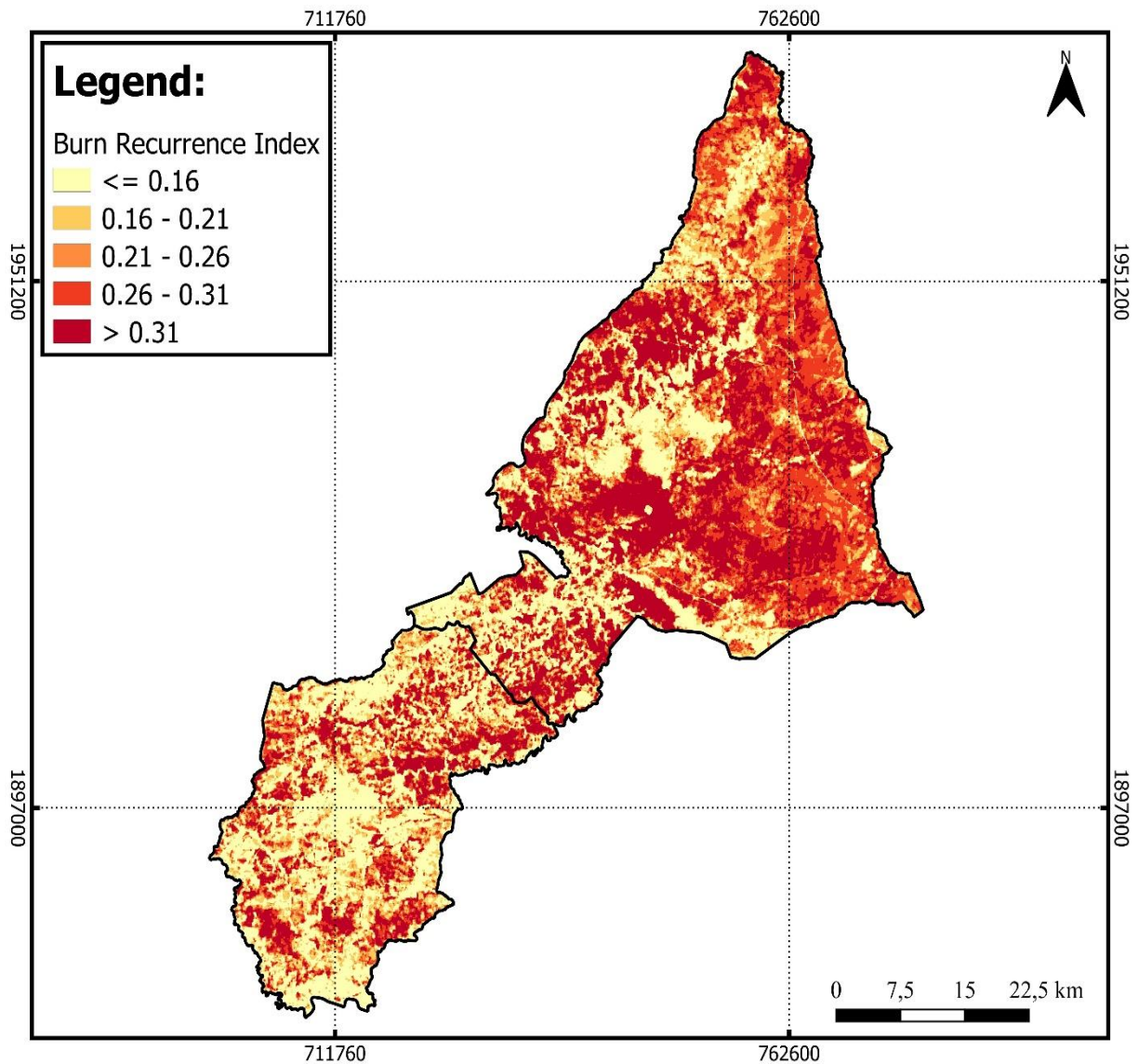


Figure 3. Burn Recurrence Index in Merure and São Marcos TIs (1985-2023).

Org.: The authors.



High values (warm colors) indicate that the area has been burned multiple times, while low values indicate that the area has been burned few or no times. The map allows for the visualization of spatial occurrence patterns, particularly in this case, where most part of the TIs are severely affected by fire. Areas with a high frequency of fires tend to experience greater environmental impacts, such as biodiversity loss and degradation of the topsoil layer. In this case, this map can serve as an important tool for identifying regions of higher vulnerability that require specific management actions.

4. Final remarks

This study investigates the impact of wildfires on Indigenous Lands in the Brazilian Cerrado, focusing on the São Marcos and Merure territories of the Xavante and Bororo people from 1985 to 2023. Here we emphasize the impact of fire on traditional communities in the Brazilian Cerrado, as highlighted, close to São Marcos and Merure territories of the Xavante and Bororo people. The results found motivate further studies to assess the physical and environmental conditions of the areas most affected by fire, especially the condition of the vegetation and climatic factors.

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